MICROELECTRONIC DATA AND CONTROL TRANSMISSION SYSTEM FOR DYNAMIC WIND-TUNNEL TESTING

by

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SUMMARY

This paper describes a microelectronic data and control transmission system designed for use in a wind tunnel where access to the test model is not practical during a relatively long period of time covering a series of test conditions. It provides for remote control of various electromechanical transducers in the model and the complete remote setup capability on the data system. The overall system is capable of transmitting up to 20 high-response data signals from the model and up to 54 auxiliary control functions to the model over a single 1/16-inch-diameter cable.

INTRODUCTION

Langley Research Center has been conducting research in the area of dynamic response of aircraft to gust and turbulent airstream loads. The primary facility for conducting this research is the Transonic Dynamics Wind Tunnel. The operation of this facility is illustrated in the first figure. The test model is suspended in the test section of the tunnel on a pair of orthogonal support cables which provide a high degree of freedom in movement

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about all three axes as well as in the vertical and lateral directions. A turbulent airstream is created by oscillating vanes upstream of the model and a freon atmosphere is employed to obtain the proper scaling. All of the data obtained in the model and control signals required to trim or "fly" the model must be transmitted between the control room and the model via an umbilical cable. A wire telemetry system was developed for this which utilizes a 1/16-inch-diameter coaxial transmission cable. The performance requirements for this system are summarized in figure 2. First, this system had to be capable of the simultaneous transmission and recording of up to 20, relatively high response (200 Hz), data signals from the model to the control room over phase matched channels. Second, due to the extreme variation of test conditions and the use of a freon atmosphere, the sensitivity and zero offset of each channel had to be variable remotely from the control room. Third, since the model is essentially flown in the tunnel by a pilot located in the control room, a remote control capability had to be provided for actuation of electrical motors within the model. Finally, the overall system must be physically suited for installation in the relatively small models used. The guidelines were that a full installation should occupy no more than 200 cubic inches and weigh no more than 10 pounds with reduced installations being correspondingly smaller.

To accomplish this performance, a system was designed which employs frequency multiplex transmission of data from the model to the control room and time multiplex transmission of controls from the control room to the model. This approach satisfied the requirements for a moderate number of relatively high response matched data channels and a large number of relatively low response control channels. The system was designed in a modular form with six binary control channels per module and five data channels per module.

DESCRIPTION

(a) General

The overall system design is shown in the block diagram in figure 3. The analog signals obtained from transducers in the model are applied directly or through an input selector unit to the five-channel modulator unit. This unit generates a frequency modulated carrier for each input, which is then transmitted via the coaxial cable to the carrier converter unit in the control console. The group of five carriers is then converted to a frequency spectrum suitable for recording on one tape track at 7-1/2 inches per second tape speed. These carriers are also applied to discriminators to provide analog outputs for display and further processing.

The control code generator provides the required signals for control of motors within the model and the sensitivity and zero offset of data pre-amplifiers contained in the data modulator. The control signal generated is in a pcm form and is transmitted over the cable via an amplitude modulated carrier. The control code contains individually addressed, six-bit control words with the total number of words per frame being variable depending on the number of modules in use. This minimizes the equipment required in the model at the expense of transmission bandwidth. The control carrier is received in the receiver/decoder which separates the control data from the address data. The control data are then routed to the appropriate storage registers in the terminal units. The control room instrumentation is shown in figure 4 and a typical model installation is shown in figure 5.

(b) Transmission

The basic transmission system employed is shown in figure 6. The control carrier is located at 10.7 MHz and occupies a 30 KHz bandwidth. The 20 carriers employed for transmission of the data are located between 95 and 190 KHz with a carrier deviation of ± 1 KHz, a spacing of 3.75 KHz within a five-channel group and 10.625 KHz between groups. The selection of these frequencies minimizes the intermodulation noise by locating all second-order carrier cross products and the adjacent group converted carriers outside the bands of interest. In addition, individual carrier filtering in the group converters and passive multicouplers is employed. The rms noise level due to intermodulation is less than 0.1 percent relative to the peak-to-peak full-scale deviation.

(c) Data Modulator

The signal processing and modulation circuitry contained in the model for each data channel is shown in figure 7. The signal obtained from the transducer is amplified in a low noise preamplifier, processed in a second amplifier for remote control of offset and sensitivity, and applied to a modulator to generate a frequency modulated carrier for transmission. The modulator unit is constructed on a plug-in, subassembly basis and is shown in figure 8. The primary subassemblies contained in this unit are: the signal conditioner, the frequency modulated oscillator, the five-channel multicoupler, and the control system shift registers. The signal conditioner is fabricated in a card form as shown in figure 9 and contains 2 dc amplifiers, a digital-to-analog converter, and a variable feedback network utilizing two miniature relays. The input amplifier is a low noise, drift-stabilized unit having terminal connections such that it may be connected as a single-ended or differential input, high or low gain amplifier. This unit was fabricated using a hybrid, thick film, screened process. The first stages are dual npn differential transistors matched to better than 10 percent mounted in a single structure for good temperature tracking. This is followed by a differential pair of pnp transistors and a single-ended pnp output transistor. The normal drift characteristic of this type of amplifier is 2 to 3 microvolts/$^{\circ}$C; however, utilizing sensitor compensation this was reduced to less than 0.5 microvolt/$^{\circ}$C. Negative feedback is incorporated to reduce the open loop gain of 2300 to 6 or 60 providing good gain stability. The second-stage amplifier is a commercially available, monolithic operational amplifier, having a temperature drift characteristic of 5 to 10 microvolt/$^{\circ}$C. This amplifier, operating in conjunction with a remotely controlled external feedback network, provides the sensitivity control. The digital-to-analog converter is a hybrid screened circuit unit constructed on 0.6 inch by 1.2 inch by 0.02 inch alumina substrate. Screened elements are employed in the switching circuits; however, due to the accuracy required, discrete resistors having low-temperature coefficients and tight tolerances were employed in the ladder network. This unit provides 16 offset voltages to an accuracy of ±0.3 percent of the incremental value. The fm oscillator, multi-coupler subassembly is shown in figure 10. The oscillators employed are high frequency (95 to 190 KHz center frequency), constant bandwidth (2 KHz) units having a zero stability of approximately 2 percent of full scale for 25° C temperature variation. The multiplexing circuit consists of five amplifiers followed by a passive L.C. multicoupler.

The control system subassembly is shown in figure 11. This unit consists of six I.C. (integrated circuit) shift registers. The control words are continually being received in a temporary register. Upon receipt of a pulse from an address line, the information contained in the temporary register is transferred, in parallel form, to one of the five storage registers associated with the five data channels. These registers operate the digital-to-analog converter and the feedback networks on the signal conditioner board.

(d) Receiver/Decoder

A block diagram of the receiver/decoder used for receiving the control signals in the model is given in figure 12. The control signal format consists of a series of six-bit control words, where each one is individually addressed with a five-bit address word, and followed by a sync pulse. This unit detects the received signal and separates the address and control words through the use of a bit counter reset with the sync pulse. The control words are gated out to the terminal units and the address words are decoded in an address matrix. Figure 13 is a photograph of this unit. I.C. logic is employed for the decoding of the detected signal. The 10.7-MHz receiver is shown in figure 14. This receiver is a two-stage TRF unit incorporating agc and pulse detection. Since this is a wire system, this receiver is gain limited with an overall sensitivity of -40 dBm, dynamic range of 40 dB, and bandwidth of 200 KHz. The complete unit is fabricated on an alumina substrate 0.7 inch by 1.6 inch by 0.05 inch. The passive elements and interconnection lines are formed by thick film deposition and the I.C. and discrete elements attached by solder reflow techniques.

(e) Control System Output

The basic module available for the control system output is the six-channel binary unit shown in figure 15. All the control words from the receiver/decoder enter the six-bit temporary register in a serial form. When a pulse appears on the address line associated with this channel, the control word is transferred in parallel from the temporary register to the storage register. This register drives six, DPDT, solid-state switches. Figure 16 is a photograph of this unit. The predominate weight factor in this unit is the aluminum heat sink for the switches. A weight and volume saving was achieved through the use of formex interconnecting leads, hybrid thick film switch drivers, and a printed board/I.C. combination for the storage register. These switches can provide 28 volts dc at 1.5 A continuous current.

Other modules developed for this control system include: a transducer selector unit which consists of a matrix of miniature relays for the remote selection of input transducers and a variable output unit which utilizes a full six-bit control word for the generation of an analog control voltage.

CONCLUDING REMARKS

A summary of the overall capability of this system is given in figure 17. The model instrumentation has been designed in a modular form. The total weight and volume is dependent on the number of channels being used and is approximately 6 cubic inches and 4 ounces per data channel, and 3 cubic inches and 2.0 ounces per control channel including all dc to dc converters required to operate on an unregulated 28-volt line. Its performance is such that it may be used in applications requiring acquisition of static and dynamic data of moderate accuracy with matched time-delay characteristics. The automatic recording of all control functions, including the sensitivity and zero on all data channels, minimizes the requirement for maintaining supplemental data sheets. The use of microelectronic circuits, multiplexed transmission, and remote control make this system well suited to ground facility applications where accessibility, size, and weight are prime considerations.

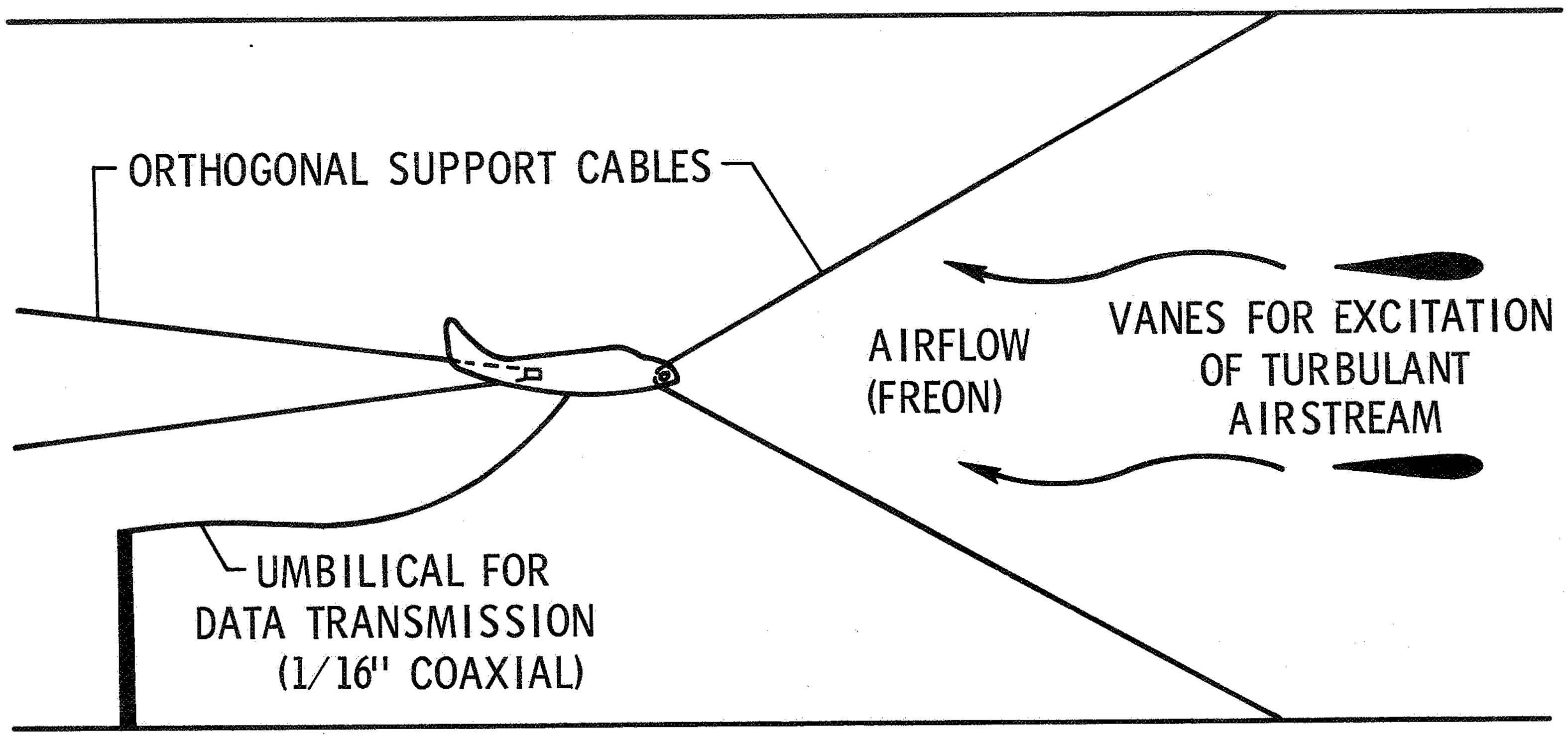

Figure 1.- Diagram of transonic dynamic wind tunnel.

- TRANSMISSION AND RECORDING OF UP TO 20 CHANNELS OF DATA.
- CONTROL OF SENSITIVITY AND ZERO OFFSET.
- REMOTE CONTROL OF MOTORS WITHIN THE MODEL.
- MINIMUM SIZE (< 200 in^3) AND WEIGHT (<10 LBS).

Figure 2.- Instrumentation system requirements.

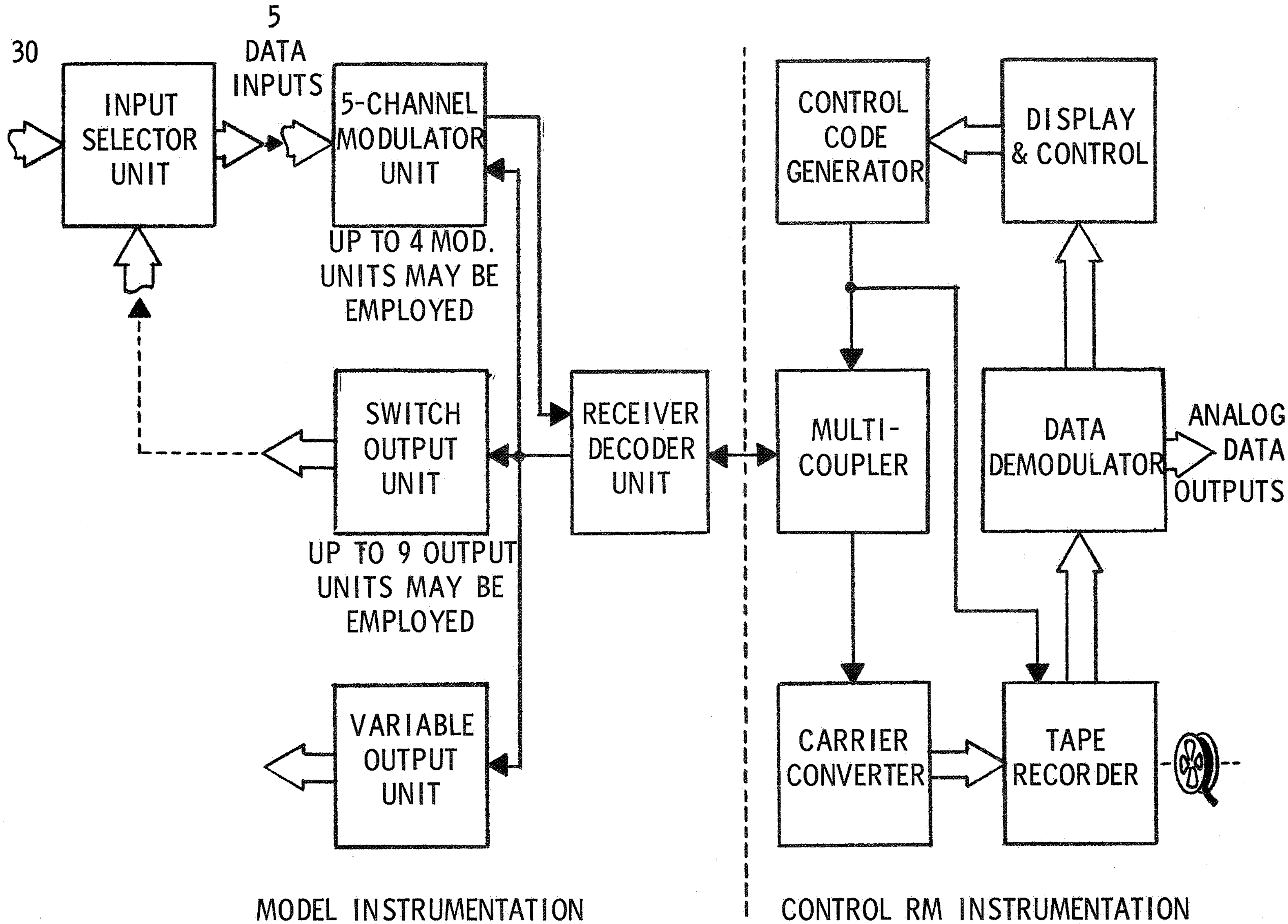

Figure 3.- System block diagram.

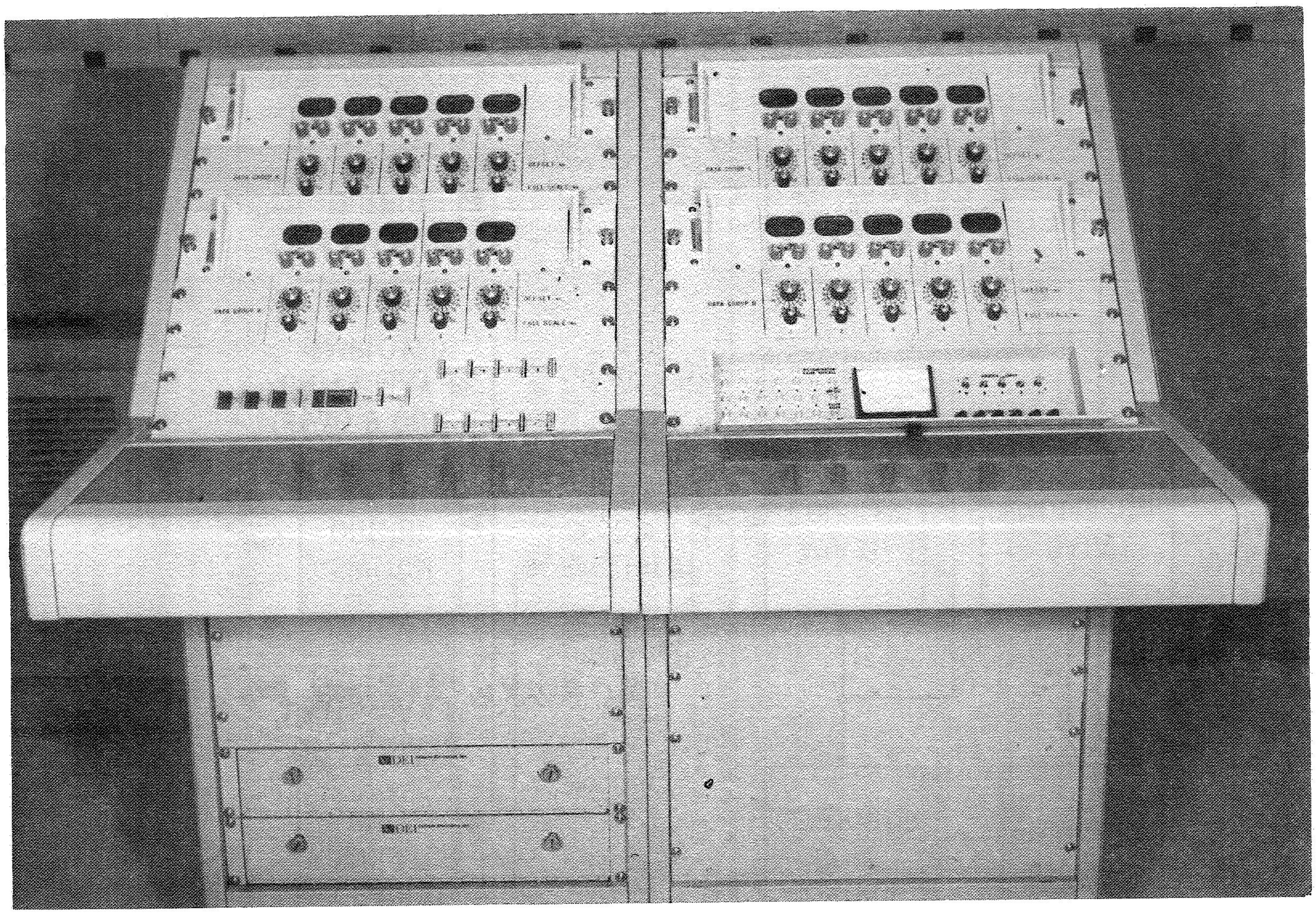

Figure 4.- Control console.

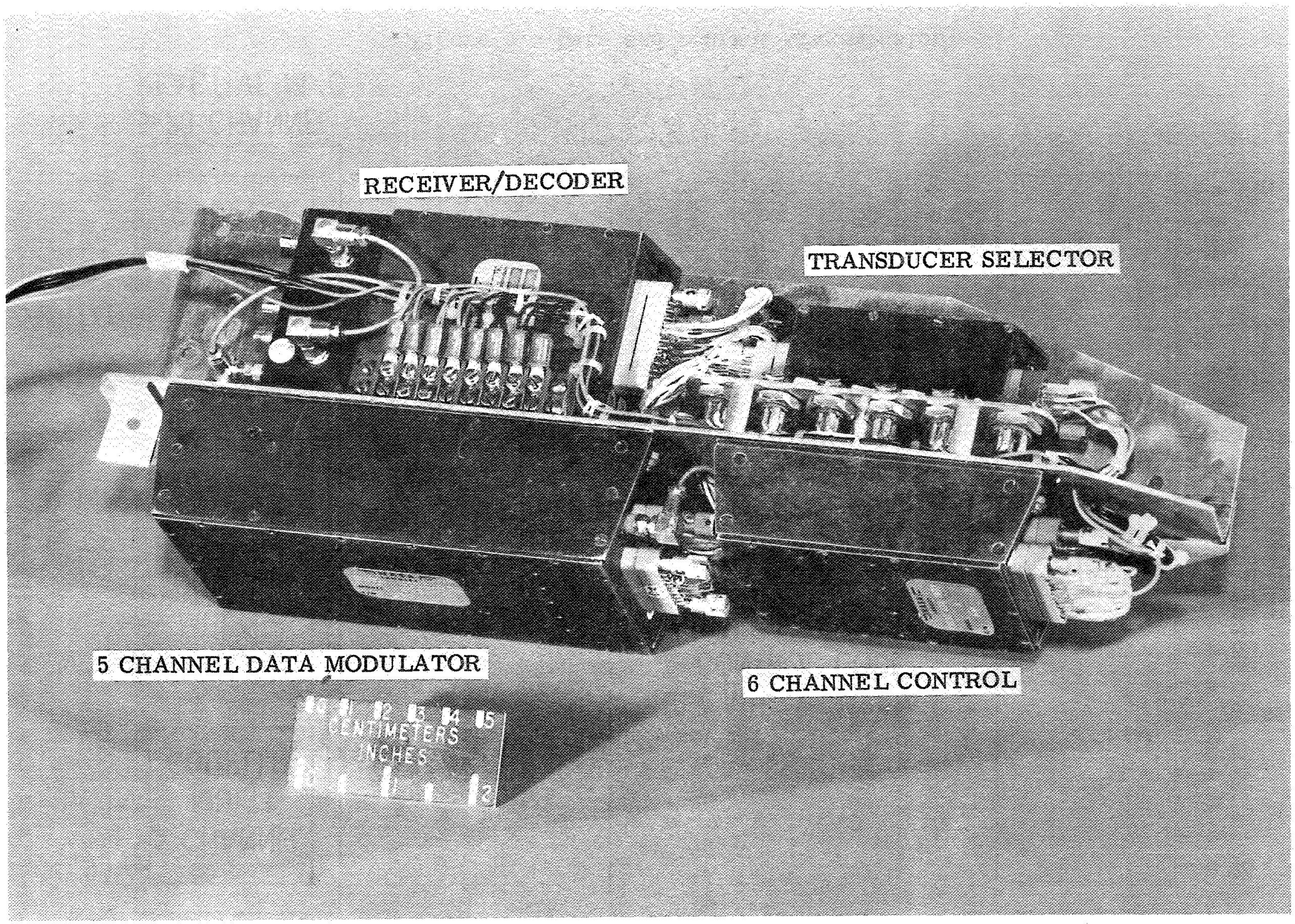

Figure 5.- Model instrumentation package.

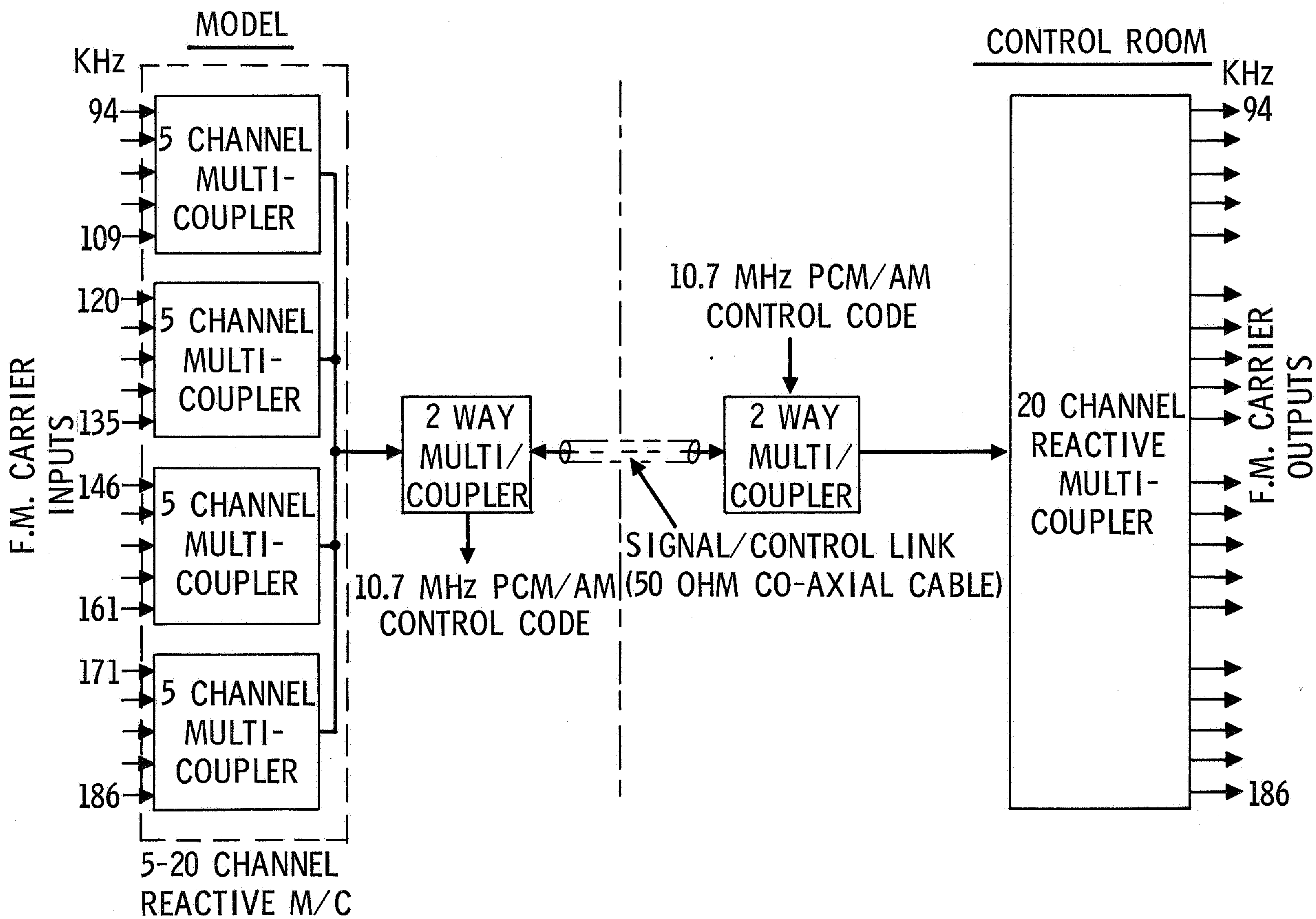

Figure 6.- Data and control transmission.

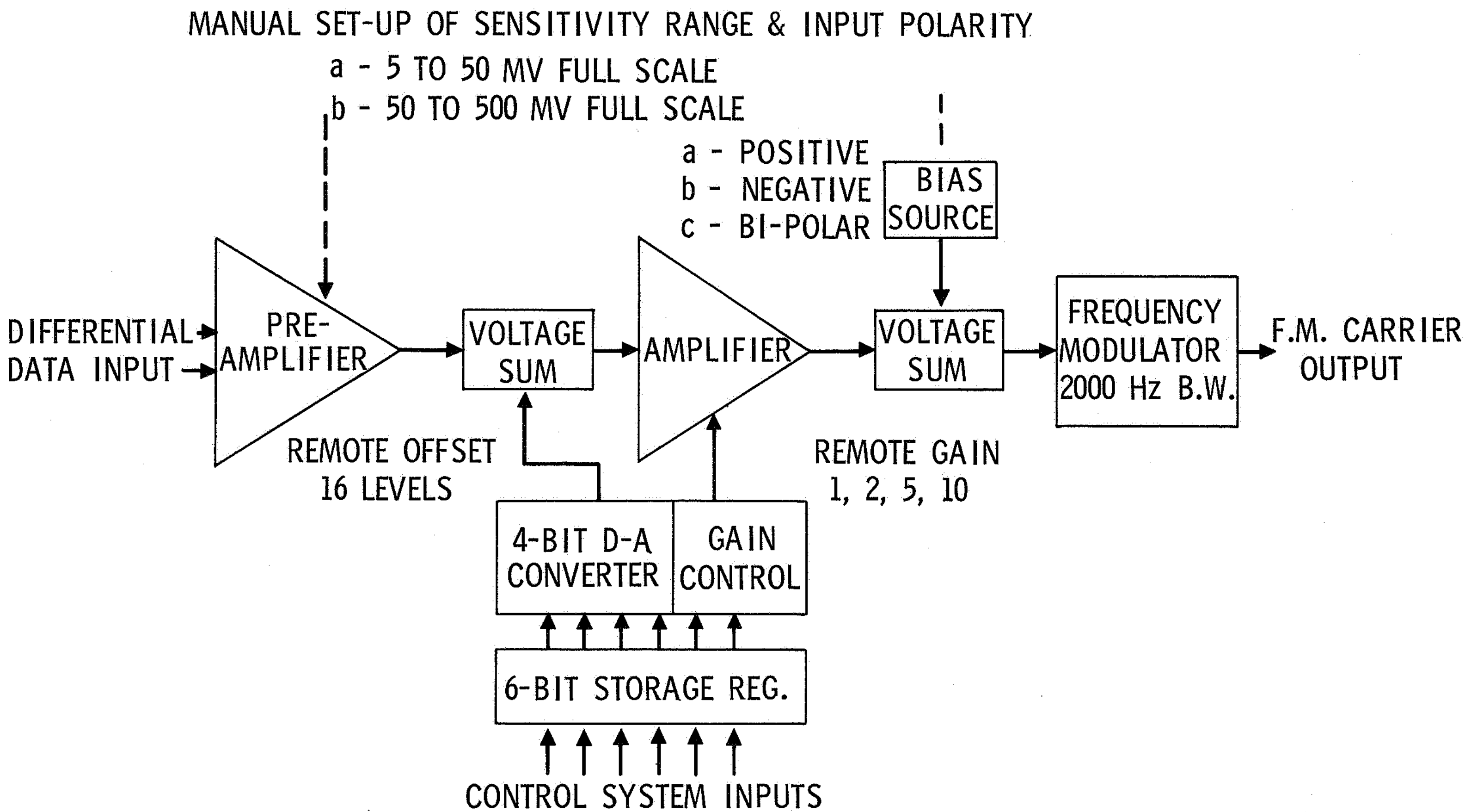

Figure 7.- Single channel data processing and modulation.

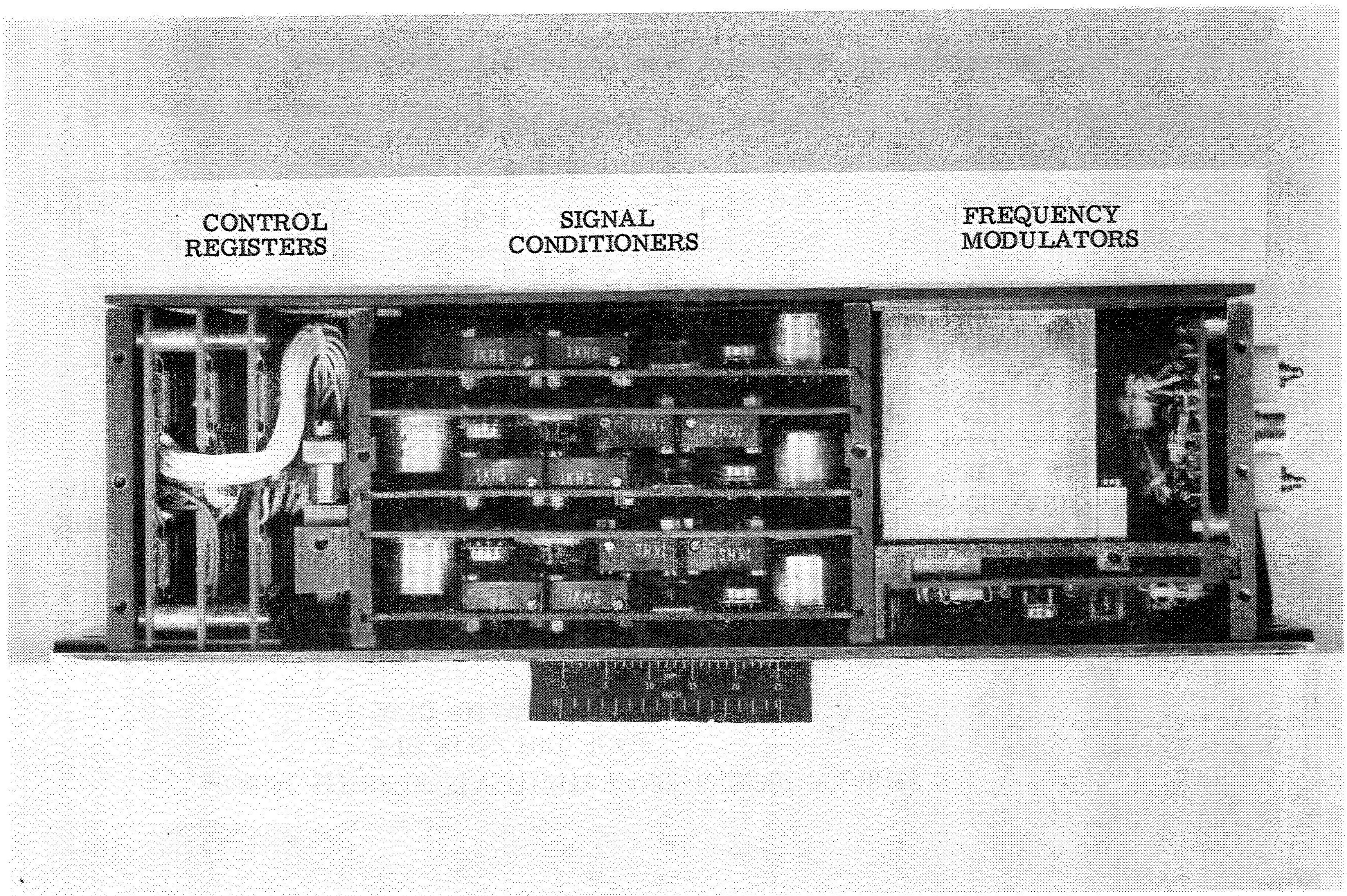

Figure 8.- Five-channel data modulator.

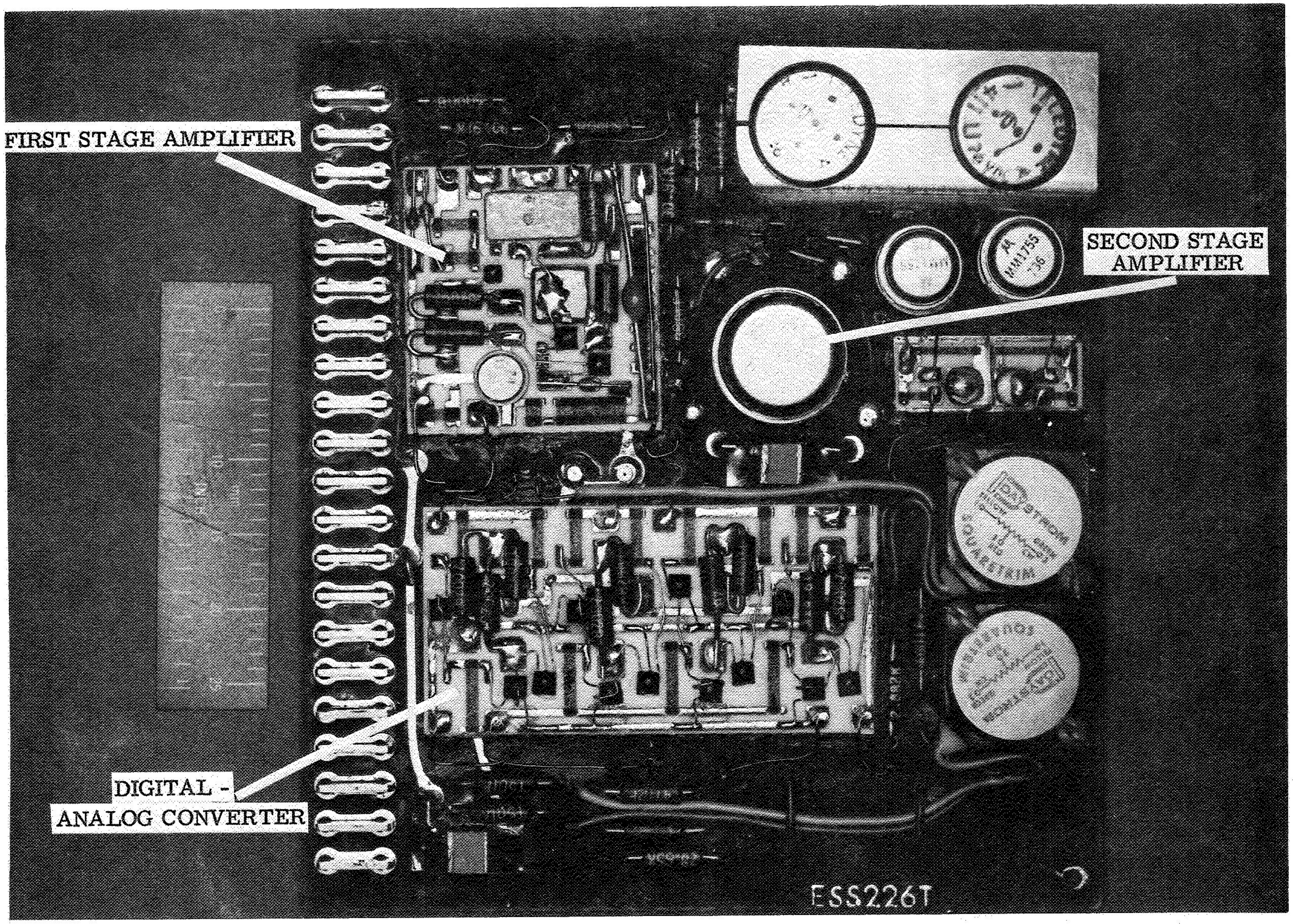

Figure 9.- Signal conditioner.

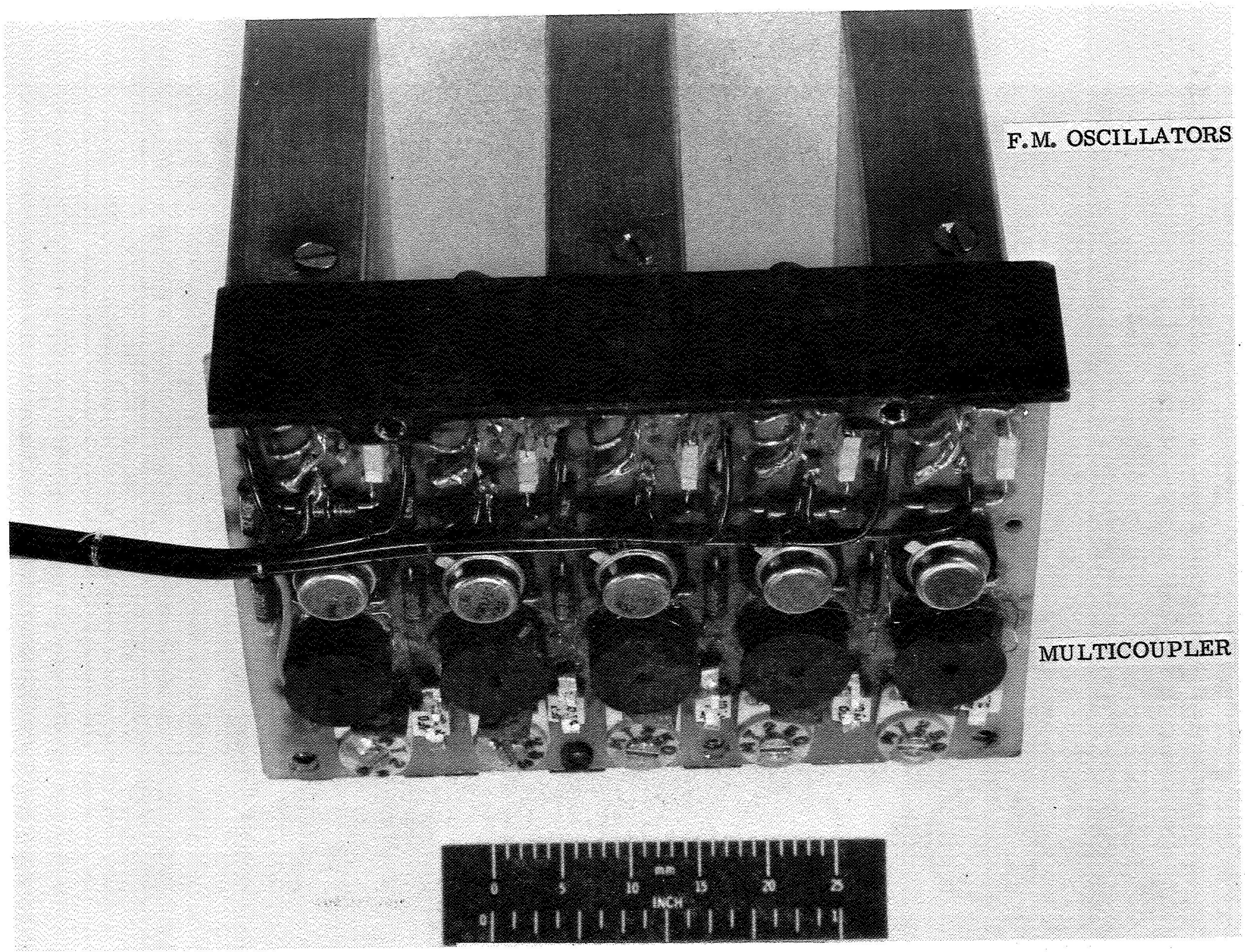

Figure 10.- Multiplex assembly.

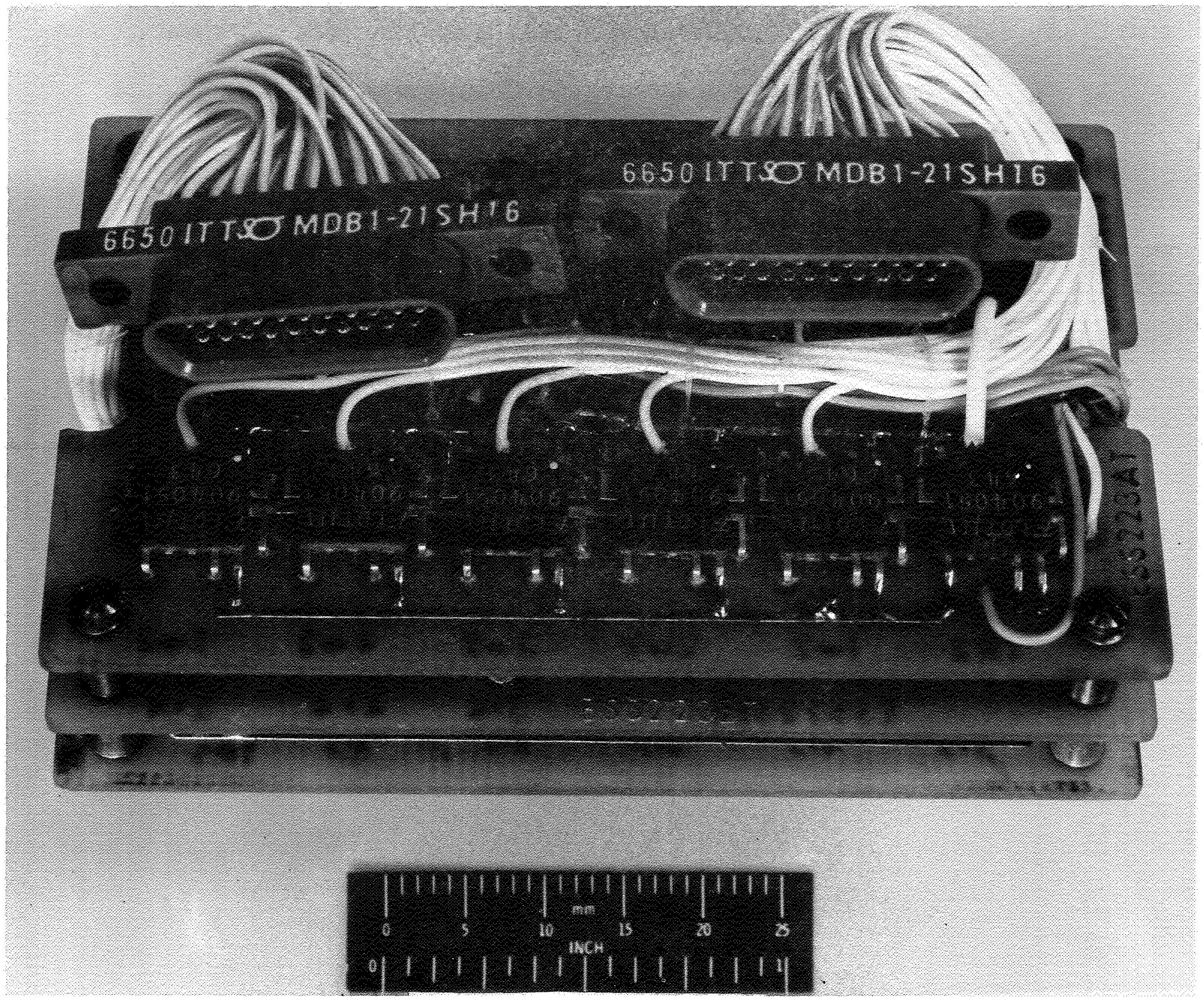

Figure 11.- Control assembly.

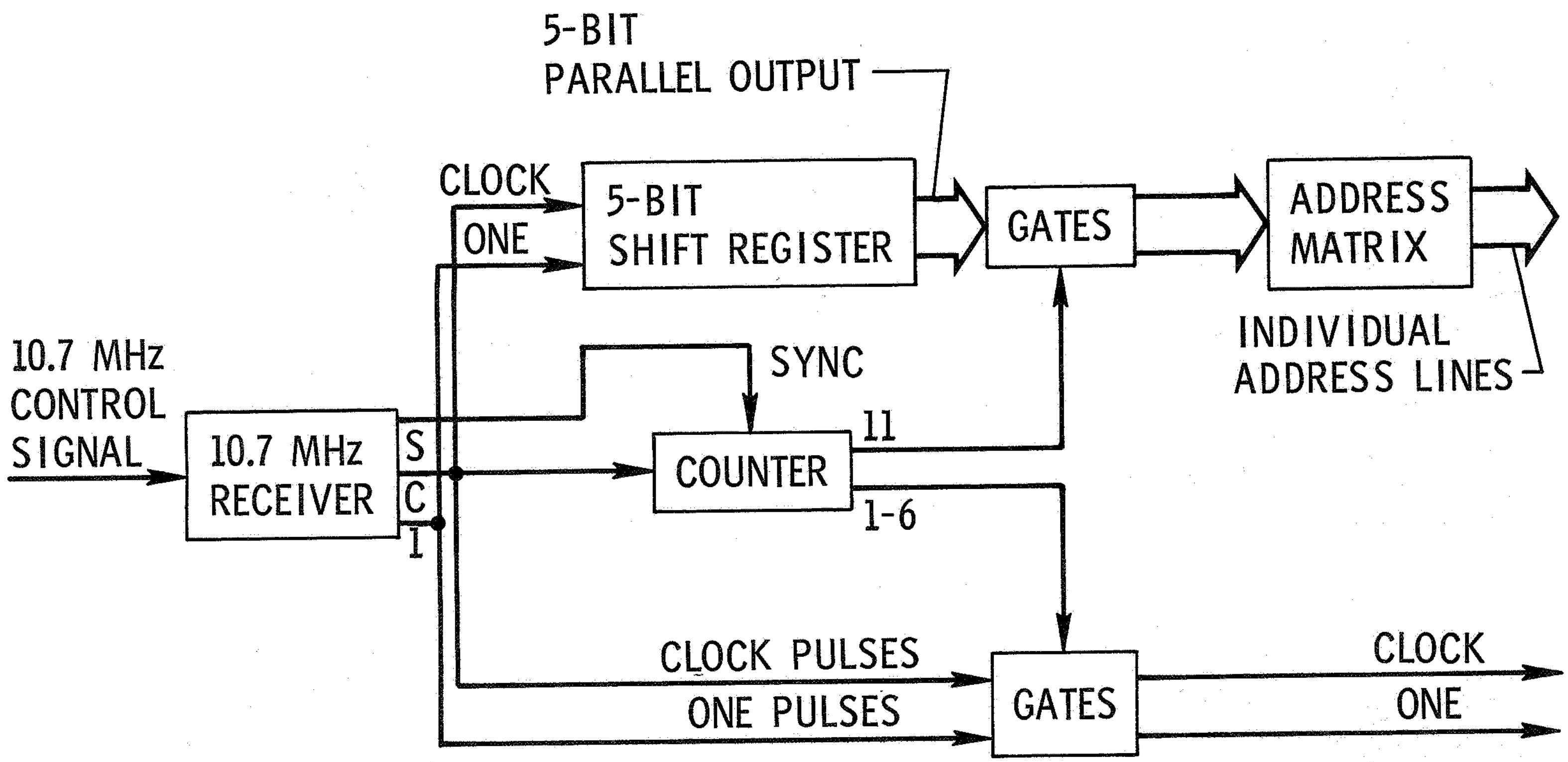

Figure 12.- Control signal receiver/decoder.

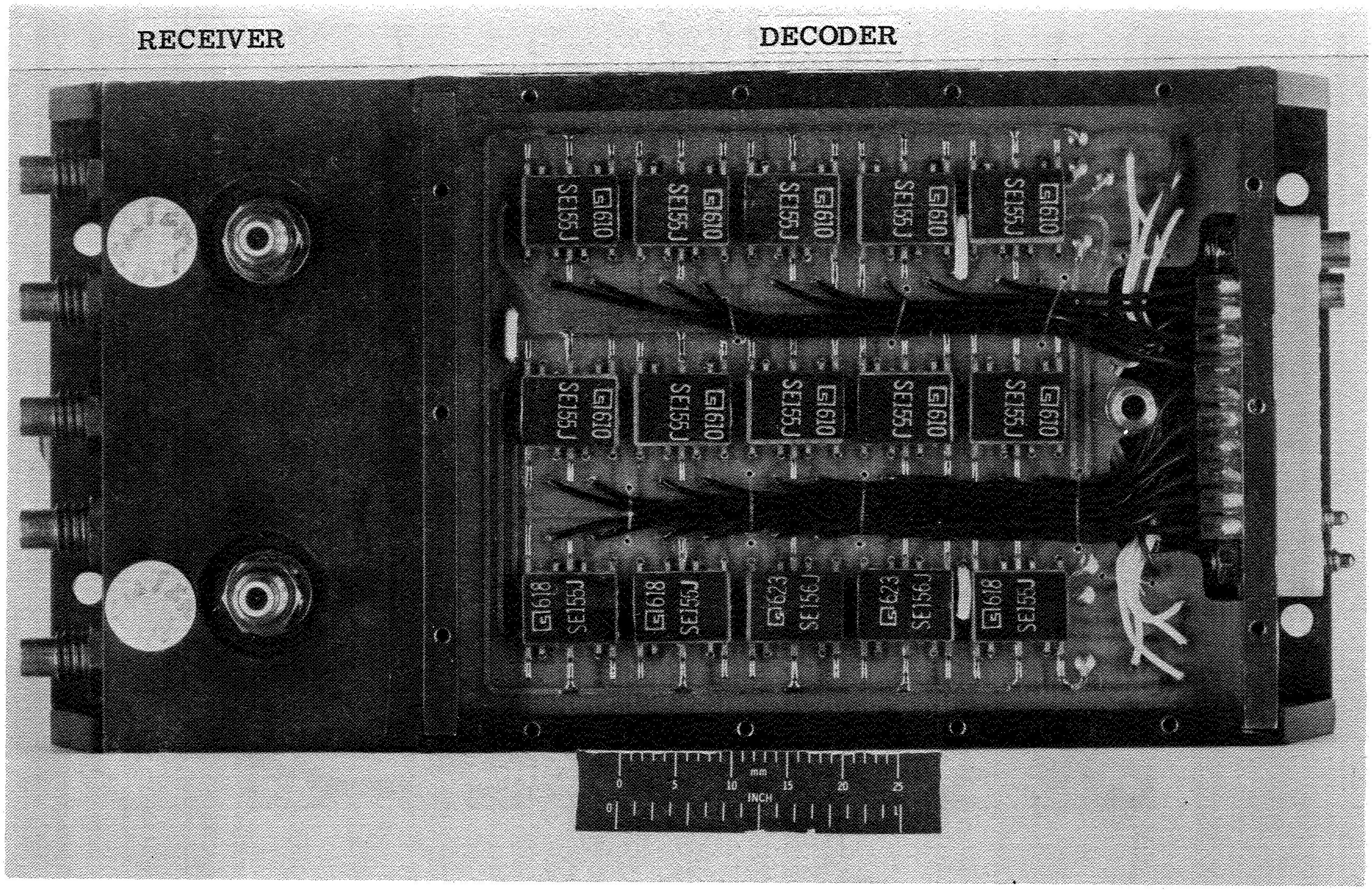

Figure 13.- Receiver/decoder.

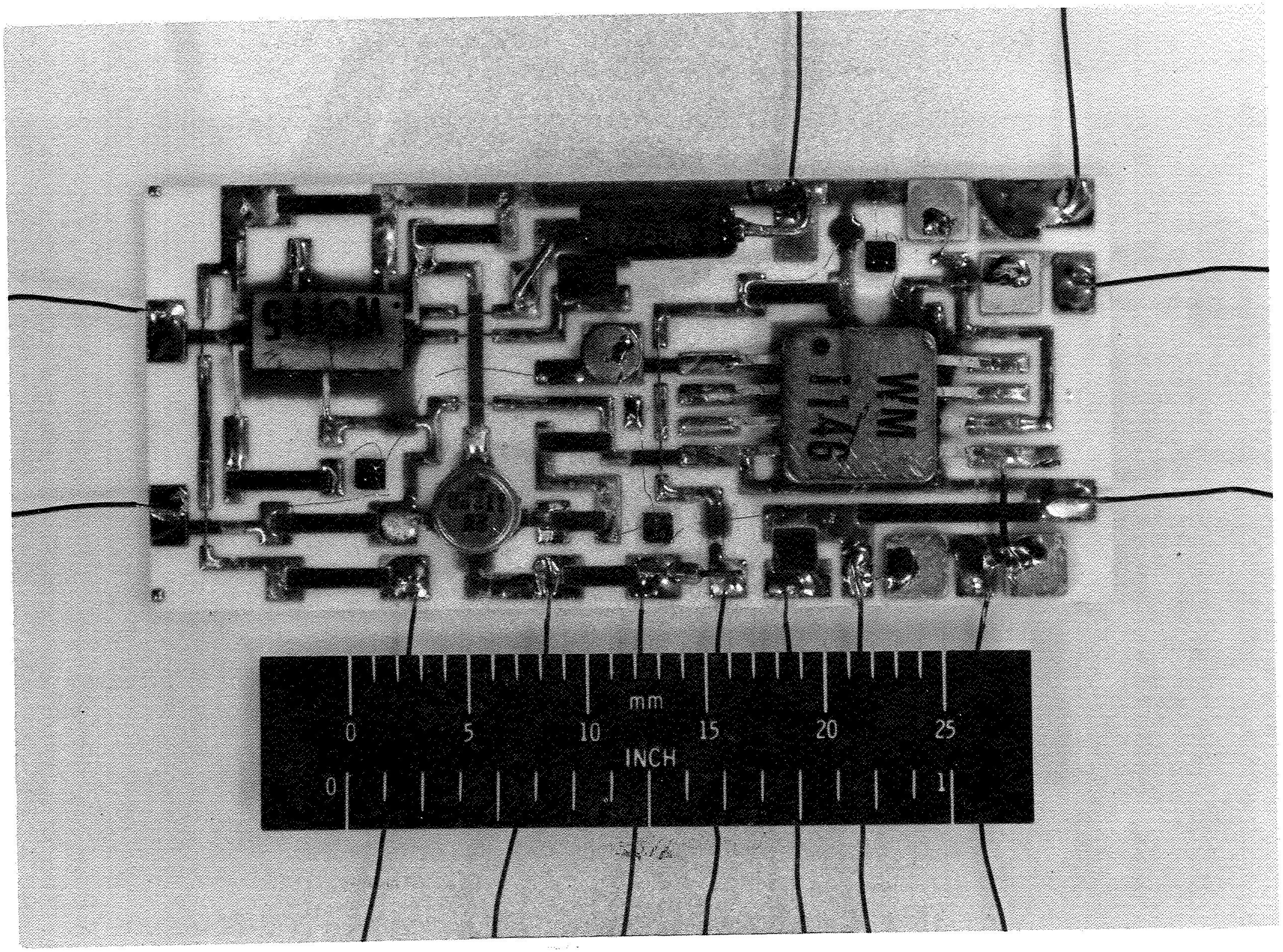

Figure 14.- 10.7 MHz receiver.

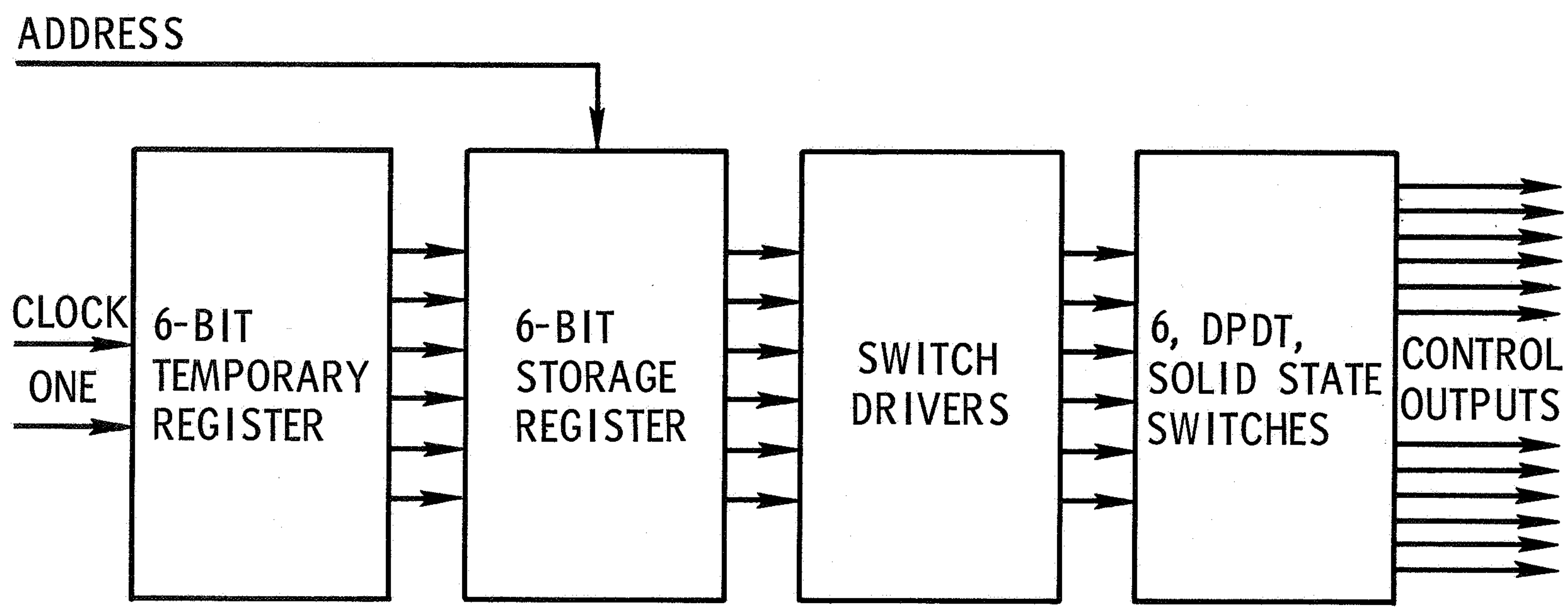

Figure 15.- Control output unit.

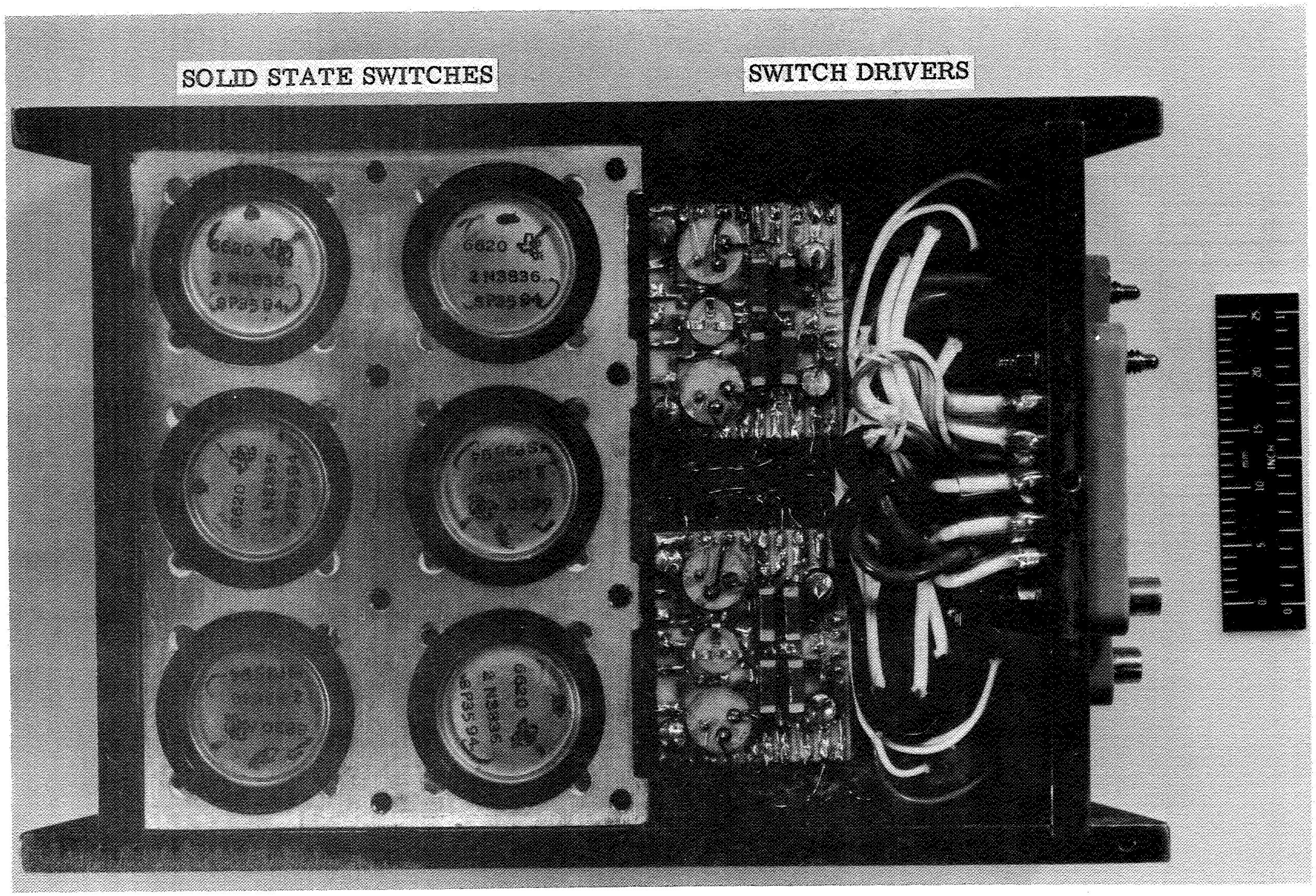

Figure 16.- Six-channel control unit.

A DATA TRANSMISSION SYSTEM	
NUMBER OF CHANNELS	5 TO 20 CHANNELS
MODULE CAPACITY	5 CHANNELS
WEIGHT	4 oz/CHANNEL
CHANNEL BANDWIDTH	D.C. TO 200Hz
CHANNEL TIME DELAY	2.1 MS ± 150μs
GAIN STABILITY	1.0 % OR LESS
ZERO STABILITY	2.0 % FOR 25^{0}C. VARIATION
LINEARITY	0.2 % OR LESS
NOISE LEVEL	0.2 % RMS/FULL SCALE
B CONTROL SYSTEM	
NUMBER OF CHANNELS	6 TO 54 CHANNELS
MODULE CAPACITY	6 CHANNELS
WEIGHT	2 oz/CHANNEL
TIME DELAY	0.1 sec MAX.
OUTPUT CAPABILITY	28 V AT 1.5 A

Figure 17.- Performance summary.

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